REPORT57B

SWEEP

SOIL AND WATER

ENVIRONMENTAL

ENHANCEMENT PROGRAM

PAMPA

PROGRAMME D'AMELIORATION

DU MILIEU PEDOLOGIQUE

ET AQUATIQUE

Canada

Ontario

SWEEP

is a $30 million federal-provincial agreement, announced May 8, 1986, designed to improve soil and water quality in southwestern Ontario over the next five years.

PURPOSES

There are two interrelated purposes to the program; first, to reduce phosphorus loadings in the Lake Erie basin from cropland run-off; and second, to improve the productivity of southwestern Ontario agriculture by reducing or arresting soil erosion that contributes to water pollution.

BACKGROUND

The Canada-U.S. Great Lakes Water Quality Agreement called for phosphorus reductions in the Lake Erie basin of 2000 tonnes per year. SWEEP is part of the Canadian agreement, calling for reductions of 300 tonnes per year — 200 from croplands and 100 from industrial and municipal sources.

PAMPA

est une entente fédérale-provinciale de 30 millions de dollars, annoncée le 8 mai 1986, et destinée à améliorer la qualité du sol et de l'eau dans le Sud-ouest de l'Ontario.

SES BUTS

Les deux buts de PAMPA sont: en premier lieu de réduire de 200 tonnes par an d'ici 1990 le déversement dans le lac Erie de phosphore provenant des terres agricoles, et de maintenir ou d'accroître la productivité agricole du Sud-ouest de l'Ontario, en réduisant ou en empêchant l'érosion et la dégradation du sol.

SES GRANDES LIGNES

L'entente entre le Canada et les États-Unis sur la qualité de l'eau des Grands Lacs prévoyait de réduire de 2 000 tonnes par an la pollution due au phosphore dans le bassin du lac Erie. PAMPA fait partie de cette entente qui réduira cette pollution de 300 tonnes par an — 200 tonnes provenant des terres agricoles et 100 tonnes provenant de sources industrielles et municipales.

TECHNOLOGY EVALUATION AND DEVELOPMENT SUB-PROGRAM

EFFECT OF WINTER RYE MULCHES AND FERTILIZER AMENDMENTS ON NUTRIENT AND WEED DYNAMICS IN NO-TILL SOYBEANS

FINAL REPORT

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Effect of Winter Rye Mulches and Fertilizer Amendments on Nutrient and Weed Dynamics in No-Till Soybeans

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Executive Summary

In the early 1980's, weed scientists' identified winter rye to be an effective weed suppressing mulch for no-till production systems. The term allelopathy is frequently used to describe the weed suppressing effect of the winter rye. However, comprehensive field data supporting allelopathy as a major mechanism of weed suppression for high C:N ratio cover crops such as winter rye is lacking. No studies in the literature could be identified which examined the effect of a winter rye cover crop on soil nutrients and weeds. However, a number of studies by soil scientists have recently indicated that rye cover crops reduce soil nitrogen. As well, weed scientists have identified that some annual weeds are more responsive to high soil nutrient levels than other weeds or crops.

This study examined if rye cover crops contribute to weed suppression in no-till systems by reducing soil nutrient levels and hence weed pressure from N responsive annual weeds. Experiments were conducted to examine: 1) the mulch (or physical) effects and 2) the fertility effects of a no-till rye cover crop on nutrient and weed dynamics in no-till soybeans. The objectives were to: 1) identify the effects of a rye cover crop on soil nutrients and 2) to separate the nutritional effects from physical and chemical (allelopathic) ones that are responsible for weed suppression in no-till soybeans.

Soil nutrient data indicated that rye plots had low soil nitrate levels at the time of soybean planting but nitrogen levels in control plots were also relatively low when measured shortly after planting. Soybeans sampled 4 weeks after planting showed delayed growth where rye had been planted as a fall cover crop in both experiments. However, nutritional deficiencies in the soybeans were not evident 8 weeks after soybean planting in both experiments. In the mulch experiment, rye cover crops grown in place and left in place (providing physical, chemical and soil nutrient effects of a mulch) resulted in approximately 1/5 the weed biomass of bare plots (no mulch) and 1/3 the weed biomass of: a rye mulch moved in place (providing physical and chemical effects of a rye mulch); a poplar excelsior mulch moved in place (providing a physical effect of a mulch) and a plot in which the rye was grown in place but removed after soybean planting (providing a soil nutrient effect of a mulch). In the fertility experiment, the addition of 75 kg N/ha to the rye plots increased weed growth by 400% and caused lamb's-quarters to become a major weed species.

In summary, one of the weed suppressing characteristics of a rye cover crop appeared to be related to its' effect on nutrient availability. The physical mulch effect also appeared to be significant in reducing weed biomass. This study indicated that these two mechanisms together play an important role in providing weed control for farmers developing low herbicide, no-till soybean systems.

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I. Introduction

Cover crops are grown specifically to perform the following functions: reduce soil erosion, increase organic matter thereby improving soil structure, enhance nutrient cycling and decrease weeds, insects and plant pathogens. Watershed studies have also indicated that the combination of the use of cover crops and conservation tillage results in small volumes of run-off and significant reductions in total P loadings (Langdale et al., 1985). The combined use of cover crops and reduced tillage appears to be a promising approach in both reducing P loadings and maintaining or improving soil quality. These are the Soil and Water Environmental Enhancement Program's major objectives.

Rye cover crops are valuable for increasing soil cover but provide little short term economic benefit to the farmer. From preliminary observations, we found that one of the most promising ways to get an economic return from rye is to use it as a no-till mulch to reduce herbicide requirements. The rye is killed using a low rate of Glyphosate and provides significant residual weed control if sufficient surface mulch is obtained. While the residual weed control effect of winter rye is thought to be due to "allelopathy" there is significant evidence to suggest that other factors may be involved. In addition to the physical effect of the rye mulch, one of the main effects on weeds may be soil nutrient manipulation by the rye (see literature review). Specific weeds are known to be favoured by certain soil nutrient conditions. The main emphasis of this project was to investigate the effect of no-till rye mulches on nutrient and weed dynamics. Our hypothesis was that the rye mulch was affecting soil nutrients in two ways:

1) rapid spring growth of the rye depletes soil nitrates so that little nitrate remains in the surface soil at the time of soybean planting;
2) rye cover crops have a residual weed control effect after being killed because the high C:N ratio of the cover crop results in nutrient immobilization by the microbial biomass.

II. Literature Review

Currently the theory being used to explain the effect of a rye mulch on weeds is that of allelopathy. The term is used to describe the inhibition of growth or development of one species due to chemicals released into the environment by another. Proof of allelopathy relies on isolation and identification of compounds responsible for the phytotoxicity. A number of compounds have been identified (Barnes et al. 1986). However, when the phytotoxins are applied to weeds under non-sterile soil conditions the phytotoxicity decreases (Barnes and Putnam, 1986). Field proof of allelopathy with rye cover crops is relatively weak. Barnes and Putnam (1983) found that residues of fall planted, spring killed rye reduced total weed biomass by 68 - 95% when compared to controls with no residue. To separate the physical and chemical effects of

rye on weed growth, the researchers established a control consisting of a mulch of poplar wood shavings added to the soil. The rye cover crop plots contained 35% less weed biomass than the poplar mulched plots. The authors concluded that allelopathy was occurring. However, the rye mulch was grown in place (thereby affecting soil nutrient levels) while the poplar mulch was simply added onto the soil surface. Similar "evidence" of rye allelopathy has been reported in greenhouse trials where rye was grown in place and where poplar chips were added to the soil surface (Putnam and Defrank, 1983).

The role of cover crops in the manipulation of soil fertility and the resulting effect on weeds has received little scientific investigation. There is significant evidence that cover crops can affect nitrogen, phosphorus and potassium supply in the soil (reviewed in Samson et al., 1990). As well it has been demonstrated that certain common weeds are favoured by high nitrogen levels including:

- quack grass (Cussans, 1973)
- lady's thumb (Freyman et al., 1989)
- mustard (Alkamper et al., 1979)
- lamb's-quarters (Freyman et al., 1989; Dyck and Liebman, 1991),
- foxtail (Staniforth, 1962)
- and wild oats (Reinertsen et al.,1984)

In addition some weeds such as pigweed (Vengris et al., 1955; Hoveland et al., 1975) and lamb's-quarters (Vengris et al., 1955) have been found to grow poorly on low P soils. While applying fertilizer to crops is thought to be generally advantageous it may be detrimental if weed control is not adequate. In a comprehensive review paper on the influence of fertilizer applications on weed infestations, Alkamper (1976) concluded that weeds are capable of absorbing nutrients faster and in relatively larger amounts than crops and thus benefit greatly from fertilization.

While it is well documented that legume cover crops can replace fertilizer N as a nutrient source, investigations into the effect of N fertilizer versus legume N fertilizer sources on weeds are only beginning. In corn, Dyck and Liebman (1991) compared the effect of spring incorporated crimson clover and ammonium nitrate fertilizer on weeds. After ten weeks, lamb's-quarters biomass was 30 % lower where crimson clover was the N source. The authors suggested that crop rotations involving legumes may provide significant weed suppression benefits in corn cropping systems as they release their nitrogen more slowly than fertilizer N sources which provide high levels of available N early in the season.

Some cover crops with high carbon-nitrogen ratios, have been found to immobilize nitrogen after incorporation (such as white mustard (Crowther and Mirchandani, 1931), and ryegrass (Breland, 1990)). Breland (1990) considered that any species with a nitrogen content of 1.2-1.8 % causes N immobilization in the form of microbial biomass. While Doran et al.(1987), found that death of microbial biomass following incorporation of hairy vetch (which contains approximately 4.3 % N) can be a major source of N for corn. The general rule is that species with a high carbon :

nitrogen (C:N) ratio immobilize nitrogen while cover crops with a low C:N ratio liberate nitrogen. The C:N ratios of a number of cover crops are listed in Table 1.

Table 1. Above Ground Nitrogen Content and C:N Ratio of Selected Cover Crops.

Species	C:N ratio	Above Ground N Content (%)	
Hairy Vetch	11:1	4.3	Maitland and Christie, 1989
Red Clover	14:1	3.1	Maitland and Christie, 1989
Crimson Clover	16:1	2.8	Wagger, 1987; Samson et al., 1990
White Mustard:late	26:1	1.5	Crowther and Mirchandani, 1931
Winter Rye: early	32:1	-	Wagger, 1987
late	38:1	-	Wagger, 1987
Annual Ryegrass	34:1	1.3	Wivstad, 1990

Reducing soil nitrates is a well identified effect of cover crops. It has been extensively documented with brassica catch crops (reviewed by Strebel et al., 1989 and Samson et al. 1992). Other research has shown that rye cover crops can reduce soil nitrate levels at the time of main crop planting. In Ontario, Samson et al. (1992) found that rye cover crops reduced soil nitrates from 8.1 to 2.5 ppm in the surface 20 cm of soil. This reduction in soil nitrates under a no-till rye cover is similar to results obtained by Brinsfield and Staver (1991) and Hoyt and Mikkelsen (1991). Other research has also indicated that rye can play an important role in reducing nitrate loss over winter (Muller et al., 1989; Staver et al., 1991). However, the residual effect of a no-till rye cover crop on soil nitrates in the top few cm of the soil where annual weeds germinate, has not been effectively documented.

Summary

1. Many of the high C:N ratio species are termed allelopathic, they include brassica species (de Almeida et al., 1985) and a number of cereals such as rye, wheat, sorghum, and barley (Putnam et al., 1983).

2. High C:N ratio species generally are 1) nitrogen consuming species when they grow (depleting soil nitrates as dry matter production increases) and 2) cause nutrient immobilization in the form of microbial biomass following their growth.

3. Many of the weeds which are suppressed by "allelopathic chemicals" are known to be high N feeders such as lamb's-quarters, and lady's thumb. These weeds form small seeds which do not have great energy reserves. In effect they are dependent on soil nutrients for establishment.

4. The crops which are least affected by "allelopathic chemicals" are generally large seeded (thereby providing large N reserves in the seed for early plant development) and nitrogen fixing species such as soybeans, snapbeans or peas (thereby providing their own N in a soil depleted of N).

III. Materials and Methods

The cropping history of the field was as follows: soybeans were grown in 1989, winter wheat was no-till drilled after harvest and harvested in 1990. Red clover was sown into the wheat in the spring of 1990 but a poor clover stand resulted. In the fall of 1990 the site was disked to kill the remaining red clover plants. In October, 1990, a rye cover crop strip and a control (bare) strip were set out on the site and replicated three times. The winter rye (var. common) cover crop was planted October 1, 1990 at 130 kg/ha using a 4.5 m wide grain drill. The control (bare) strip was an unseeded strip which had some remaining residue cover from the winter wheat straw. Each experimental strip was 4.5 m wide and 28 m long. Seven subplots (4.5 m by 4m) were established in each of the rye or bare strips. The first 4 subplots (16 metres) of each strip were used for a fertility experiment and the last 3 subplots (12 metres) of each strip used for a mulch experiment.

Rye biomass was sampled on May 22, 1991 and the site was sprayed with a 2.5 l/ha Glyphosate (Round-Up) and 1.25 l/ha 2,4-D tank mix. Both the rye and control strips were sprayed. This was the standard herbicide mixture used by the farmer as a spring contact herbicide. Soybeans (var. NK 1990) were planted in 77 cm rows with a no-till drill on May 23 at approximately 80 kg/ha (approximately 375,000 seeds/ha). The rye was mowed with a Jari mower to a height of 4 cm that same day.

Mulch Experiment

The mulch experiment consisted of 5 treatments to separate out the physical, chemical and soil nutrient effects of the rye mulch:

1) rye mulch grown in place and left in place (physical, chemical and soil nutrient effects of the mulch);
2) rye removed (soil nutrient effects of the mulch);
3) rye moved in place (physical and chemical effects of the mulch);
4) poplar excelsior moved in place (physical effect of the mulch);
5) bare plot (no mulch).

Treatments 1 & 2 were established on the rye strip and treatments 3-5 on the bare strip. The rye moved in place (treatment 3) was rye removed from treatment 2. A poplar excelsior mulch (American excelsior #732 fine) equal to 75% of the rye biomass yield was spread on treatment 4 plots. A lower poplar mulch rate was suggested by staff at Michigan State University where the original rye allelopathy work was done.

Fertility Experiment

In the fertility experiment, three fertility treatments and an unfertilized control were established on each of the rye and bare strips. Fertilizer was broadcast by hand prior to rye mowing. The phosphate was applied as triple superphosphate (0-46-0) and the nitrogen as ammonium nitrate (34-0-0).

Soil Analysis

Background soil samples were taken in the rye and bare plots at 20 cm intervals to a depth of 1 meter, 4 days after planting soybeans. Soil samples were taken at 0-20 cm, 20-40 cm and 40-60 cm depths 4 and 8 weeks after planting in both experiments. Soil samples were taken from 1 bore hole in the soybean row from the centre of each plot at each sampling. Moist soil (20 g) was weighed into a 250 ml Erlenmeyer flask and 100 ml 2*M* KCl added. The flasks were shaken for 1 hour on a rotary shaker and the extractant filtered through a Whatman # 40 filter paper and stored at 4° C. The extracts were analyzed on a TRAACS 800 autoanalyzer for NH_4^+ using the Berthelot reaction (Technicon industrial method 780-86T, Tarrytown, N.Y., U.S.A.) and for NO_3^- plus NO_2^- with a Cd reduction column (Technicon industrial method 818-87T, Tarrytown, N.Y., U.S.A.). Total soil extractable inorganic nitrogen content was then calculated as the sum of NH_4^+, NO_3^- and NO_2^-. Microbial biomass C and biomass N was also determined using a modified chloroform fumigation-incubation technique as described by Drury et al.,(1991).

Tissue Analysis

Four weeks after planting 10 soybean plants from each plot were sampled for biomass and nitrogen content. Eight weeks after planting the top trifoliate of 10 plants was sampled for nitrogen content. Plant samples were dried, ground and digested using a kjeldahl procedure with a block digester. The digests were analyzed for total N concentration using the Berthelot reaction as described above except that sodium hydroxide was added to the EDTA solution to neutralize the acid in the digests.

Weeds

Weeds were harvested using four quadrats per plot. A preselected grid was used to establish a random sampling at 8 possible locations in each subplot. Each quadrat consisted of a 1.3 m by 0.77 m wood frame which was straddled over a soybean row at the preselected locations. The weeds were cut off at the soil surface, identified, enumerated and dry matter biomass determined during the first week of September. The weed species collected in this study were: barnyard grass (*Echinochloa crusgali*), foxtail (*Setaria viridis*), lamb's-quarters (*Chenopodium album*), ragweed (*Ambrosia artemisifolia*), red root pigweed (*Amaranthus retroflexus*) and nightshade (*Solanum americanum*). All other weeds were included in a mixed weed category.

Yields

Three metres of rows 2-5 was harvested from each plot on October 7-8, threshed using a stationary Hege small plot combine, weighed and moisture content determined with a Dickey John grain moisture meter. The soybean yields were determined and expressed on a 14% moisture basis.

IV. Results and Discussion

At the time the experiments were established in mid-late May the rye had headed and produced a considerable amount of biomass (approximately 5.2 t/ha). No significant differences were observed in the soil nitrate levels taken from the main plots (rye versus bare) in the mulch experiment at the time of first soil sampling, 4 days after planting. A heavy rain (59.4 mm) fell after planting and prior to nitrate sampling which may have affected the results of the first nitrate sampling (Table 2). A high degree of variability was obtained in some of the microbial biomass data as well as the soil nitrate data. The microbial biomass data were not included in the final report as some them are being reanalyzed. One explanation of the high degree of variability in the soil test results may have been related to sampling. The selection of one bore hole in the soybean row for sampling was probably not the most appropriate for the main soil factors being evaluated. Probably it would have been more appropriate to perform more extensive surface sampling and include all areas of the plot (as N fixation by the row planted soybeans may have affected surface soil N measurements most in the row). The nitrate data at the 8 week sampling date was probably affected both by nitrogen fixation from the soybeans as well as N uptake by weed growth.

Table 2. Background NH_4-N and NO_3-N of the Bare and Rye Cover Crop Plots (4 days after soybean planting)

Treatment	Depth (cm)	NH_4-N (mg / kg)	NO_3-N (mg / kg)
Bare	0-20	2.71 a	6.72 a
	20-40	1.89 a	5.54 a
	40-60	1.47 a	3.82 a
	60-80	1.85 a	3.32 a
	80-100	1.85 a	2.69 a
Rye	0-20	3.41 a	3.97 a
	20-40	2.48 a	3.54 a
	40-60	2.03 a	1.97 a
	60-80	2.06 a	0.95 a
	80-100	2.25 a	1.00 a
Bare	0-100	1.95 a	4.42 a
Rye	0-100	2.34 a	2.12 a
CV		27.5%	40.3%

Mulch Experiment

Soil Nutrients

Significant differences between rye plots and bare treatments were identified at the lower sampling depths (20-40 cm and 40-60 cm) when sampling occurred 4 weeks after planting (Table 3). Relatively large error terms probably masked any treatment differences which may have been present in the surface soil horizon when sampling occurred 4 weeks after planting. Soil nitrate levels eight weeks after planting were lower than at the 4 week sampling period. Weeds may have taken up significant quantities of N by this stage. Soil moisture levels also declined from the 4 to 8 week sampling period. At the 4 week sampling, highest soil moisture levels were associated with treatments which had a cover moved in place. Plots with no cover appeared to be lowest while plots with a rye cover crop grown in place and left in place were intermediate in soil moisture.

Table 3. Analysis of Soil Moisture and NO_3-N content 4 and 8 weeks after Soybean Planting in the Mulch Experiment

Treatment	Moisture (%)	NO_3-N (mg/kg)		
sampling depth	0-20 cm	0-20 cm	20-40 cm	40-60 cm
4 weeks				
Bare	16.9 c	14.2	9.3	5.1
Poplar	18.9 ab	13.3	5.7	4.7
Rye Roots	16.1 c	12.7	3.6	2.2
Rye Tops Added	19.4 a	9.2	7.0	3.9
Rye	17.5 bc	7.7	2.3 *	0.8 *
C.V.	5.3%	47.4%	63.9%	54.3%
8 weeks				
Bare	8.9	5.0	2.0	1.6
Poplar	9.2	4.5	1.8	2.0
Rye Roots	8.8	6.1	3.3	1.9
Rye Tops Added	9.7	5.9	4.4	3.0
Rye	9.7	6.9	3.0	1.8
C.V.	16.2%	24.0%	25.8%	35.1%

Note 1. Means within the same column followed by the same letter are not significantly different according to Fishers protected LSD at the 0.05 level.

Note 2. * indicates significantly different than the control (bare) at the 0.05 level according to the LSD test.

Early Soybean Growth

Soybeans growing in a rye mulch had low plant weight and low tissue N content when measured four weeks after planting (Table 4). Visually these plants were readily identified as being smaller and paler in colour than those growing where there was no

rye mulch. Where the rye was harvested soybeans also exhibited poor early dry weight accumulation and N concentration. One potential reason for the higher initial plant growth on the poplar excelsior treatment, than the rye tops added treatment, may have been related to 2,4-D being retained by the rye residue. A limited amount of leaf cupping was observed on some soybean plots where rye was left in place or moved in place at the time of sampling at 4 weeks. When sampling was performed eight weeks after planting, % N in the soybeans was similar amongst all treatments and all soybean plots were a dark green colour.

Table 4. Tissue Analysis of Soybean Sampled 4 and 8 Weeks after Planting in the Mulch Experiment

Treatment	Dry Weight	Tissue Concentration (% N)	
	(g/ 10 plants at 4 weeks)	4 Weeks (whole plant)	8 weeks (top trifoliate)
Bare	8.77 b	3.83 ab	5.55
Poplar	10.80 a	4.09 a	5.55
Rye Roots	7.43 bc	3.46 bc	5.73
Rye Tops Added	8.13 bc	4.03 a	5.53
Rye	6.37 c	3.20 c	5.49
C.V.	11.4%	7.7%	3.6%

Note 1. Means within the same column followed by the same letter are not significantly different according to Fishers protected LSD at the 0.05 level.

Weed Biomass

Large differences in weed biomass and weed number were identified between the various mulch treatments. Weed biomass was lowest in the treatment where the rye mulch was grown in place and left in place. The control treatment produced approximately 5 times more weed biomass and 10 times greater weed populations than the rye mulch treatment (Figure 1 & Table 5). Weed biomass yields obtained from the poplar excelsior, rye removed and rye added treatments were similar. These treatments produced approximately 3500 kg/ha of weed biomass or approximately 3 times the weed biomass of the rye mulch treatment.

The predominant weeds in the trial were ragweed and lamb's-quarters. The rye mulch reduced weed biomass of these species by 92 % and 87 % respectively (Table 6). The main weed escape in the rye mulch treatment was pigweed (Figure 2). While they were few in number ($1/m^2$), the pigweed escapes tended to grow well on the rye mulch treatment probably due to the lack of competition from other weeds. The other significant weed reductions were in the number of nightshade (96% less) and foxtail (86% less) present on the rye mulch treatment compared to the control treatment (Table 7).

Figure 1 **Weed Biomass and Soybean Yield**
from the Mulch Experiment on Doug Smith's Farm

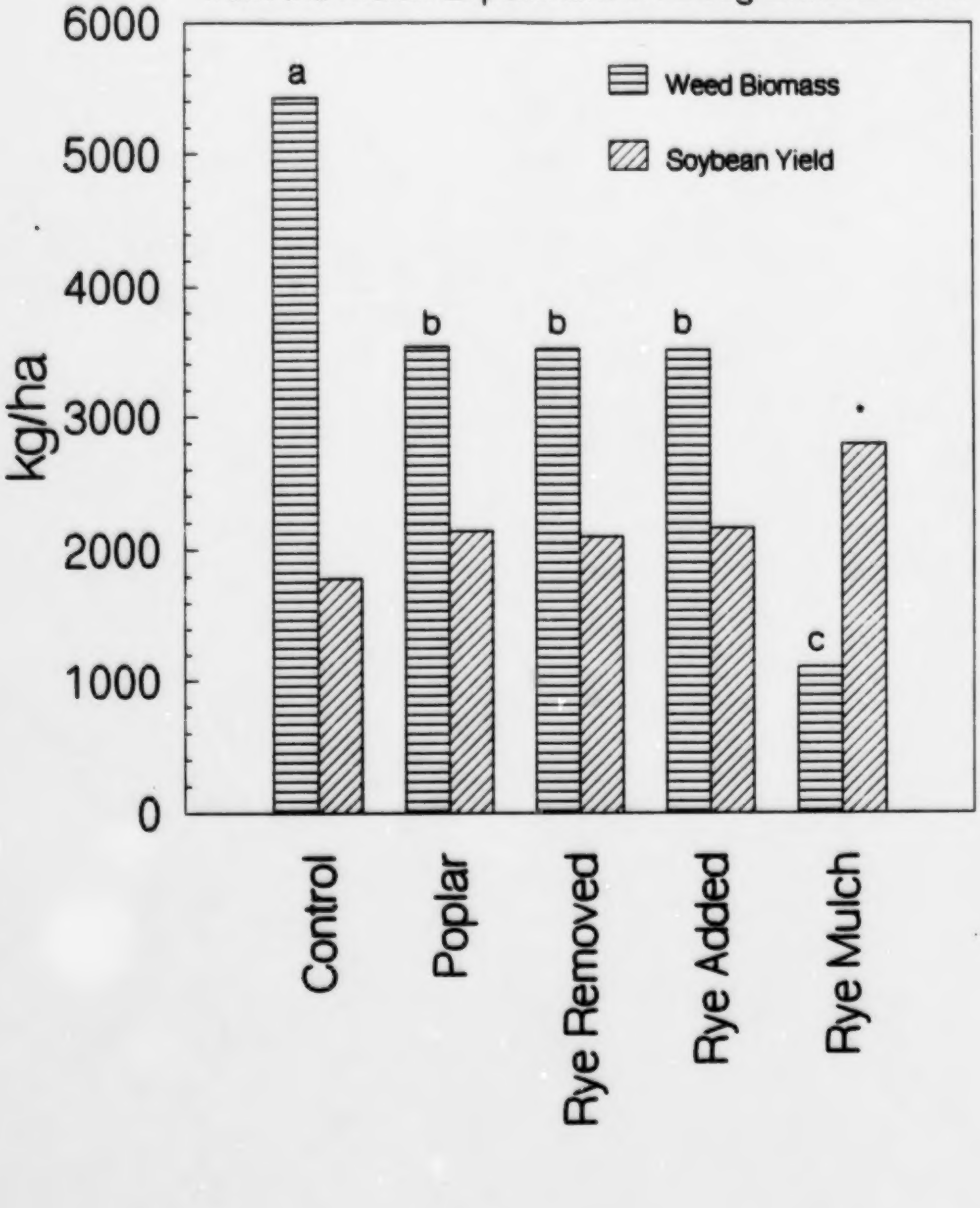
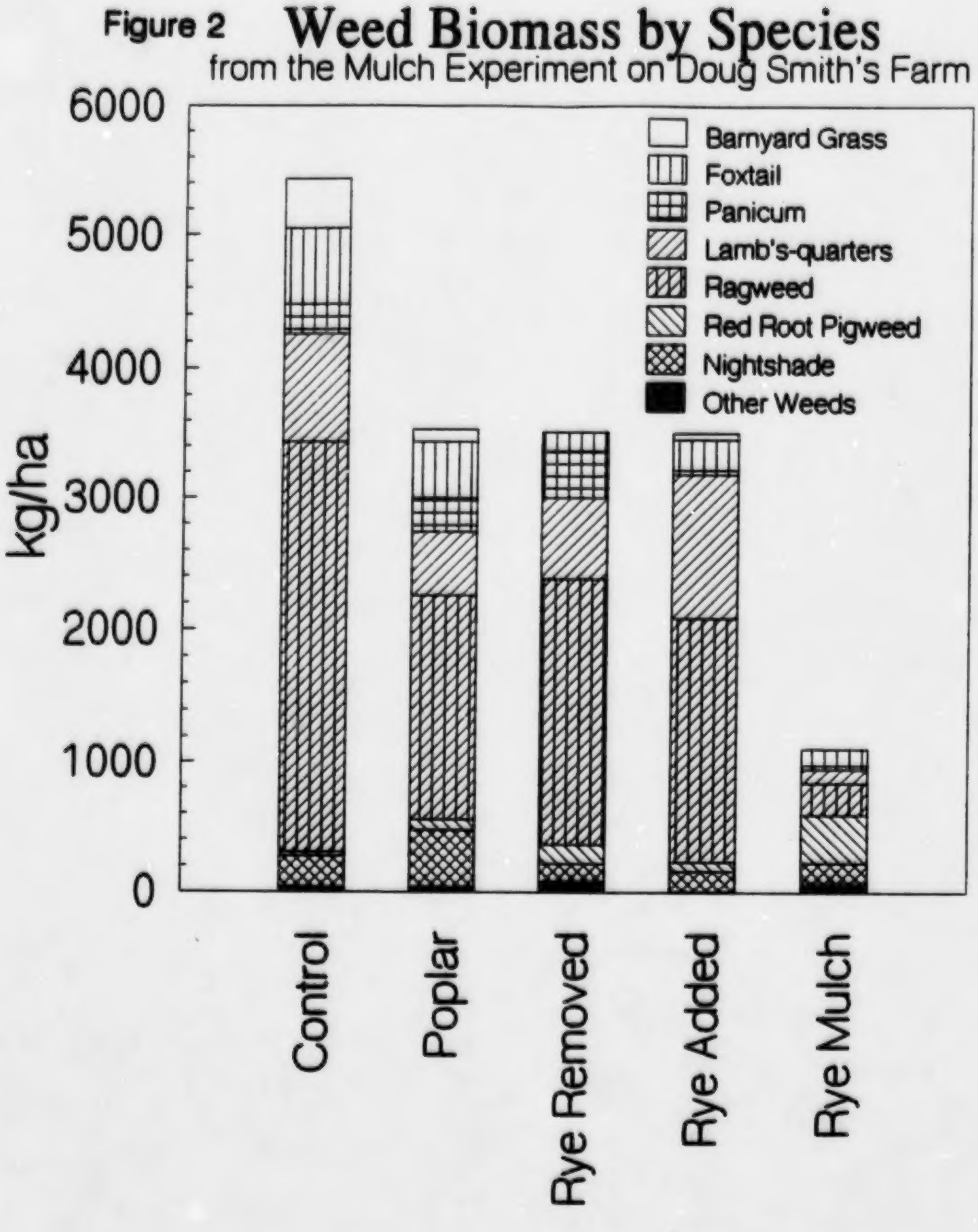


Figure 2



Weed Biomass by Species
from the Mulch Experiment on Doug Smith's Farm
6000
5000
4000
3000
2000
1000
0
kg/ha
Barnyard Grass
Foxtail
Panicum
Lamb's-quarters
Ragweed
Red Root Pigweed
Nightshade
Other Weeds
Control
Poplar
Rye Removed
Rye Added
Rye Mulch

Table 5. Weed populations, weed biomass and soybean yield results from the Mulch Experiment on Doug Smith's Farm in 1991.

Treatment	Weed Population			Weed Biomass			Soybean Yield	Soybean Yield	Soybean Pop.
	Broadleaves No./4 m^2	Grasses No./4 m^2	Weeds No./4 m^2	Broadleaves kg/ha	Grasses kg/ha	Weeds kg/ha	kg/ha	bu/ac	No./ha
Control	314 a	53	367 a	4228 a	1203	5430 a	1785	26.6	226,743 a
Poplar	190 ab	20	210 ab	2701 b	831	3531 b	2137	31.8	192,840 ab
Rye Removed	170 abc	24	194 ab	2941 b	567	3508 b	2093	31.1	104,258 c
Rye Added	83 bc	15	98 b	3173 b	324	3497 b	2159	32.1	188,831 ab
Rye Mulch	27 c	7 *	34 b	936 c	168 *	1104 c	2786 *	41.4 *	147,638 bc
CV (%)	50.5	86.7	49.1	19.9	88.7	17.2	18.9		26.0

* Treatment different from control

Table 6. Populations and biomass data for certain weed species from the Mulch Experiment on Doug Smith's farm in 1991.

Treatment	Barnyard Grass		Foxtail		Panicum		Lamb's-quarters		Ragweed		Red Root Pigweed		Nightshade	
	No./4 m^2	kg/ha	No./4 m^2	kg/ha	No./4 m^2	kg/ha	No./4 m^2	kg/ha	No./4 m^2	kg/ha	No./4 m^2	kg/ha	No./4 m^2	kg/ha
Control	14	380	28	572	6	221	85 a	826	27 a	3128 a	10	29	188	235
Poplar	1	100	11	439	7	259	16 b	479	18 ab	1700 b	6	81	143	437
Rye Removed	0	0	13	151	8	362	28 b	619	12 bc	2013 b	16	145	100	136
Rye Added	1	51	11	239	2	32	19 b	1092	14 bc	1855 b	6	68	41 *	151
Rye Mulch	0	0	4 *	127	2	31	3 b	105	5 c	251 c	4	364 *	8 *	160
CV (%)	245	239	83.7	93.9	73.6	82.7	45.4	68.7	32.4	21.4	106	90.8	70.2	98.3

Soybean Yield

Soybean yield appeared to be related to weed pressure. The rye mulch treatment had the best soybean yield and the weedy control plot had the lowest (Table 5). Treatments with poplar added, rye added, or rye removed performed similarly with an intermediate yield response compared to the bare or rye mulch treatment. The final plant stand was significantly lower in the treatment where the rye was removed (Table 5). Lower soybean density may have modestly reduced soybean yield in this treatment.

Fertility Experiment

Soil Nutrients

Fertilization with 75 kg N/ha increased surface soil nitrates by approximately 325% and 425% in the bare and rye plots respectively, when measured four weeks after planting (Table 7). Nitrate levels were generally much lower and less affected by the fertilizer application at the lower sampling depths at this time. Nitrate sampling eight weeks after planting indicated that levels were generally lower than at four weeks. Probably weeds became a major sink for soil N at the 8 week sampling stage (particularly on the bare plots).

Early Soybean Growth

As in the mulch trial, soybeans exhibited delayed growth and reduced N content in the rye plots of the fertility study (Table 8). On the rye plots, fertilization with N improved whole plant tissue N content and fertilization with both N and P increased plant weight when measured 4 weeks after planting (Table 9). Nitrogen uptake per 10 plants was also significantly higher on plants receiving both N and P fertilizer on the rye mulch plots. Soybeans fertilized with N and P on the rye mulch plots provided similar N contents and total N uptake levels as unfertilized bare plots. However, bare plots receiving N or N in combination with P had the highest tissue N and total N uptake levels. The results suggest that the rye cover crop reduced both N and P availability to the soybeans as 1) P fertilization alone had no measured effect on soybeans yield and 2) N fertilization alone increased tissue content but did not provide the growth response that was identified with both N and P fertilization. When the soybeans were measured by the 8 week stage no fertility effects or cover crop effects were identified on soybean N content. Soybean top trifoliate N levels were within adequate N nutrition levels at this stage (OMAF, 1991). Nitrogen fixation by the soybeans was probably well developed at the 8 week stage since soil nitrate levels were lower at the 8 week sampling date than at 4 weeks (Table 7).

Table 7. Analysis of Soil NO_3-N in the Fertility Experiment, 4 and 8 Weeks after Soybean Planting

Treatment	(kg/ha)	NO_3-N (mg/kg) 0-20 cm	20-40 cm	40-60 cm
Four Weeks				
Bare	0 N +0 P	11.2	6.4	4.0
	0 N +50 P	9.5	5.4	5.6
	75 N+0 P	34.9 *	15.4	12.1
	75 N+50 P	31.9	14.1	7.7
Rye	0 N +0 P	8.8 c	4.7	3.2
	0 N +50 P	8.5 c	4.8	1.5
	75 N+0 P	30.8 b	10.7	5.4
	75 N+50 P	42.7 a	11.8	3.7
Eight Weeks				
Bare	0 N +0 P	5.1	4.9	2.7
	0 N +50 P	4.0	3.0	1.7
	75 N+0 P	17.0	8.0	2.5
	75 N+50 P	14.3	8.7	4.7
Rye	0 N +0 P	10.1	5.7	3.9
	0 N +50 P	7.6	4.4	2.1
	75 N+0 P	15.2	7.2	4.7
	75 N+50 P	7.7	4.6	2.2

Note 1. Means within the same column followed by the same letter are not significantly different according to Fishers protected LSD at the 0.05 level.

Note 2. * indicates significantly different than the control (Bare 0 N + 0 P) at the 0.05 level according to the LSD test.

Table 8. Soybean Plant Analysis, 4 and 8 Weeks after Planting when Analyzed as a Split Plot

Treatment	Dry Weight	Total N/ 10 plants	Tissue Concentration (% N)	
	(g/ 10 plants at 4 weeks)	(mg N at 4 weeks)	4 Weeks (whole plant)	8 weeks (top trifoliate)
0 N + 0 P	8.3 b	289 b	3.36 b	5.38
0 N +50P	8.1 b	267 b	3.18 b	5.46
75 N + 0 P	9.8 a	405 a	4.10 a	5.46
75 N +50 P	9.8 a	464 a	4.13 a	5.52
CV	11.9%	15.3%	5.2%	3.3%
Bare	11.8a	468 a	3.93 a	5.43
Rye	6.9 b	245 b	3.45 b	5.48
CV	15.4%	21.0%	3.6%	5.5%

Note 1. Means within the same column followed by the same letter are not significantly different according to Fishers protected LSD at the 0.05 level.

Table 9. Soybean Plant Analysis, 4 and 8 Weeks after Planting when Analyzed Separately by Cover

Treatment		Dry Weight	Total N/ 10 plants	Tissue Concentration (% N)	
	(kg/ha)	(g/ 10 plants at 4 weeks)	(mg N at 4 weeks)	4 weeks (whole plant)	8 weeks (top trifoliate)
Bare	0 N +0 P	10.5	393 b	3.74 b	5.32
	0 N +50 P	10.5	369 b	3.51 c	5.35
	75 N+0 P	12.7	542 a	4.25 a	5.55
	75 N+50 P	13.3	568 a	4.24 a	5.51
C.V.		11.8%	14.0%	2.9%	2.6%
Rye	0 N +0 P	6.17 b	184 c	2.99 b	5.44
	0 N +50 P	5.79 b	165 c	2.85 b	5.57
	75 N+0 P	6.78 b	269 b	3.95a	5.37
	75 N+50 P	8.96 a	360 a	4.01a	5.54
C.V.		10.9%	16.6%	7.2%	3.8%

Note 1. Means within the same column followed by the same letter are not significantly different according to Fishers protected LSD at the 0.05 level.

Weed Biomass

Nitrogen fertilizer increased weed biomass by approximately 400% and 50 % in the rye mulch and bare plots respectively (Figure 3). In the rye plots, lamb's-quarters and pigweed were responsible for most of the increase in weed biomass (Figure 4). The lamb's-quarters increase was the most striking as the weed was a minor species in the non-N fertilized rye plots. A significant fertility cover crop interaction was identified for this species (Table 11). As was previously mentioned, nitrate levels increased by 425% and 325% from N fertilization on the rye and bare plots respectively while weed growth increased by 400% and 50% at the same time. Probably the reason for the lower response on the bare plots was that weed biomass was approaching an upper limit as weed yields of 7-8 t dry matter per hectare were obtained.

Fertilization with phosphorus had less dramatic effects on weed biomass. There was some evidence that phosphorus reduced weed growth but this was probably related to improved soybean growth observed on some of the P- treated plots.

Soybean Yield

Nitrogen fertilization of the unweeded soybeans resulted in reduced soybean yields (Table 10). Soybean yields were inversely related to weed biomass in the fertility experiment (as was the case in the mulch experiment). Soybean yields were highest on the rye plots which received no N fertilizer and lowest on N fertilized bare plots. In some treatments, phosphorus fertilization appeared to have moderately increased yields.

Figure 3 **Weed Biomass and Soybean Yield**
from the Fertility Experiment on Doug Smith's Farm

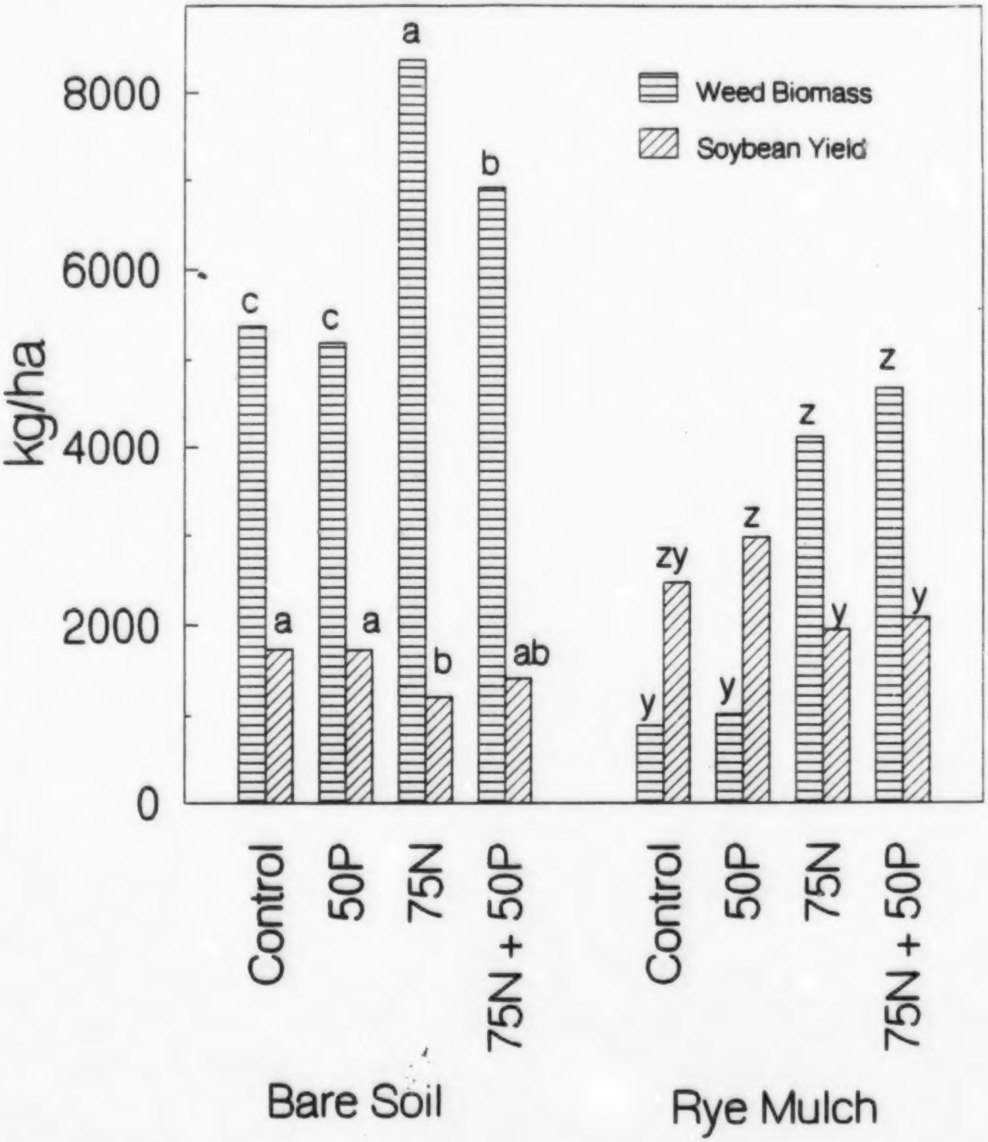


Figure 4 **Weed Biomass by Species**

from the Fertility Experiment on Doug Smith's Farm

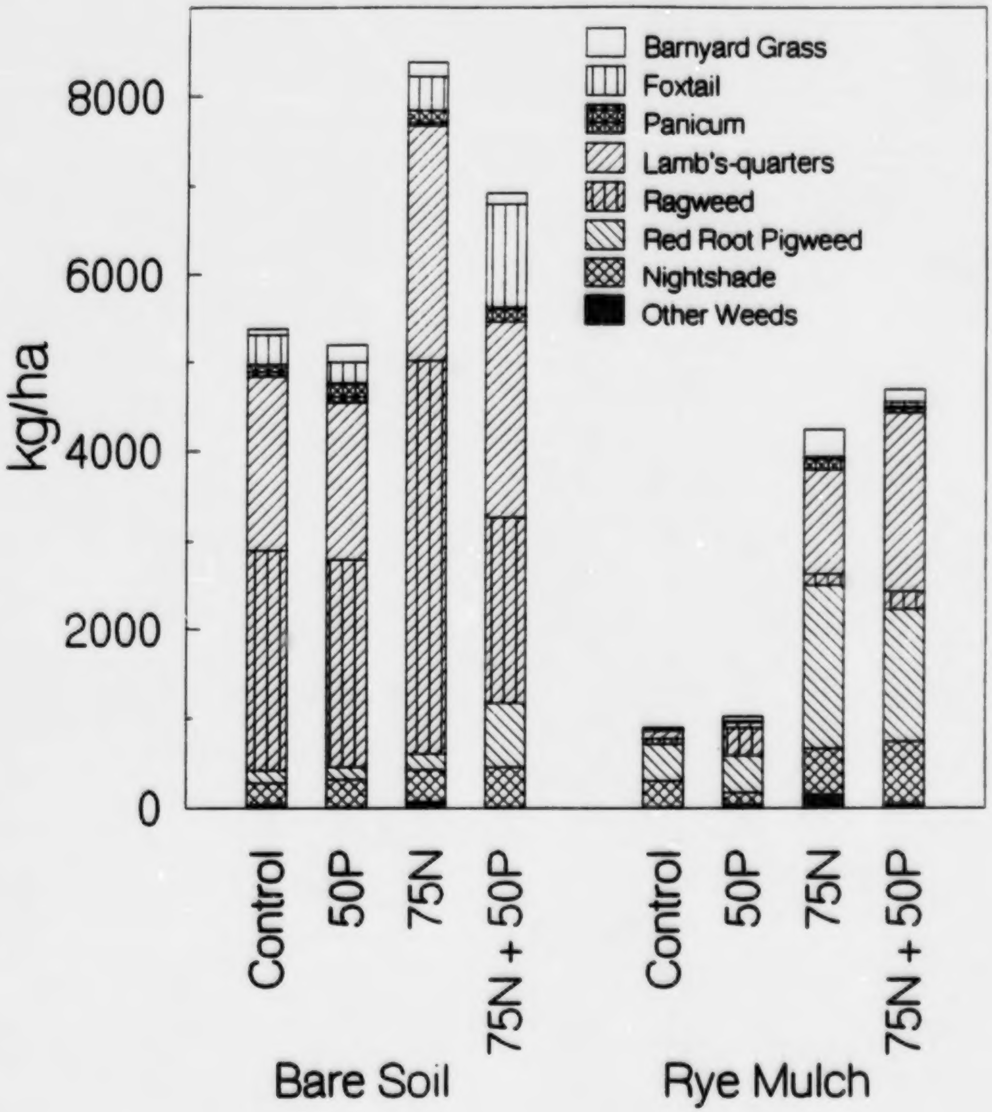


Table 10. Weed populations, weed biomass and soybean yield results from the Fertility Experiment on Doug Smith's Farm in 1991 when analysed as a split-plot design and presented as a whole.

	Weed Population			Weed Biomass					
Treatment	Broadleaves No./4 m^2	Grasses No./4 m^2	Weeds No./4 m^2	Broadleaves kg/ha	Grasses kg/ha	Weeds kg/ha	Soybean Yield kg/ha	Soybean Yield bu/ac	Soybean Pop. No./ha
Fertility									
Control	215	19	234	2834 b	297	3132 b	2102 ab	31.3 ab	203,230
50P	251	24	275	2741 b	358	3099 b	2350 a	35.0 a	213,255
75N	154	15	168	5646 a	607	6253 a	1580 c	23.5 c	197,033
75N + 50P	152	31	182	4933 a	861	5794 a	1748 bc	26.0 bc	183,545
Cover									
Bare	333 a	39	371 a	5608	854	6462	1522	22.6	240,230
Rye	53 b	5	59 b	2469	208	2676	2369	35.2	158,301
Interaction									
Fert X Cover	**	ns	*	ns	ns	ns	ns	ns	ns

Table 11. Populations and biomass data for certain weed species from the Fertility Experiment on Doug Smith's farm in 1991. The data were analysed as a split-plot design and presented as a whole.

Treatment	Barnyard Grass No./4 m^2	Barnyard Grass kg/ha	Foxtail No./4 m^2	Foxtail kg/ha	Panicum No./4 m^2	Panicum kg/ha	Lamb's-quarters No./4 m^2	Lamb's-quarters kg/ha	Ragweed No./4 m^2	Ragweed kg/ha	Red Root Pigweed No./4 m^2	Red Root Pigweed kg/ha	Nightshade No./4 m^2	Nightshade kg/ha
<u>Fertility</u>														
Control	1	34	10	178	7	76	47 a	1010 b	15	1274 b	12	275 b	136	263
50P	5	121	11	124	7	108	52 a	902 b	17	1328 b	15	276 b	159	216
75N	2	236	6	200	5	151	49 a	1908 a	16	2265 a	14	1014 ab	72	434
75N + 50P	2	127	23	622	4	111	36 b	2088 a	8	1149 b	15	1105 a	90	568
<u>Cover</u>														
Bare	4	134	24	536	9 a	170	84 a	2131	26 a	2833 a	17	295	199	332
Rye	2	124	2	26	2 b	52	7 b	822	2 b	175 b	11	1040	30	408
<u>Interaction</u>														
Fert X Cover	ns	ns	ns	ns	*	ns	***	ns	ns	*	*	ns	*	ns

V. General Discussion

The nutritional and physical effect of a rye mulch on weeds appeared to be additive. In the mulch experiment, the physical effect of a mulch (rye added or poplar excelsior added) reduced weed biomass by approximately 36% (Figure 1). Allelopathy did not appear to be a significant factor in weed suppression as no additional weed control was provided by the rye mulch moved in place over the poplar mulch moved in place. The effect of a rye cover crop grown in place but removed (providing a soil nutrient effect but no physical mulch effect) reduced weed pressure by 36%. The combined effect of a rye mulch grown in place and left in place reduced weed biomass by approximately 80% (slightly greater than physical and nutritional effects combined). Evidence of a nutrient effect provided by the rye mulch grown in place can also be observed by the lower soybean whole plant biomass and N content on the soybeans grown on the rye strips at 4 weeks after planting. Addition of 75 kg N/ha in the fertility experiment quadrupled weed biomass in the mulch plots yet weed biomass was only 1/2 that of the bare plot fertilized with 75 kg N/ha. Repeating the experiment in 1991-92 (including increasing surface soil sampling) will be necessary to more effectively understand soil nutrient dynamics under a rye mulch and its' effect on weed growth.

Some of the weeds which were cited in the literature review as being nitrogen responsive (i.e. lamb's-quarters) appeared to have been favoured by nitrogen fertilization in this study. The main factor which needs to be more fully documented is the residual nutrient immobilization effect of a rye mulch on the surface soil horizon where annual weeds germinate. Early season nutrient deprivation by the rye cover crop may also be affecting final soybean yield. This could not be assessed in the trial as no weeded check was included in the N and P fertilized rye plots.

The Glyphosate (Round-up) & 2,4-D mixture used in this study (2.5 l/ha) is not a standard rye kill mixture and was used because it was present in the farmers sprayer (for use as a spring contact herbicide in ridge-till systems). Farmers using the rye cover crop no-till system generally are using 0.8-1.25 l/ha of Round-up to kill the rye. If low rates of Glyphosate are used in this system, the use of a rye cover crop in a no-till soybean production system appears to offer an opportunity for farmers to use a no-till system with low herbicide inputs. Increasing the understanding of the effect of rye mulches on weeds and early soybean growth will help increase farmer acceptance of this system which has significant potential to reduce soil and water degradation.

In summary, rye cover crops appeared to have two main effects on weed growth in no-till soybeans:

1. Nutritional effects
2. Physical mulch effects

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